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NOTES AND LITERATURE

BIOMETRICS

Recent Quantitative Studies on Variation in Social Insects.—The social insects (ants, bees, wasps and termites) because of the differentiation of their populations into "castes," distinguishable from one another in somatic characters, present a whole series of interesting problems in variation, heredity and morphogenesis. These animals afford very alluring material with which to undertake biometrical study of various problems within the fields mentioned. It is a matter of comparative ease to get relatively large numbers of individuals. The firm exoskeleton makes measurement, and the preservation of material unchanged for future measurement, comparatively easy. Finally, in addition to the wide variety of somatic structure to be found in the several castes, the relation of these castes to sexual and asexual modes of reproduction also adds to the intrinsic biological interest and usefulness of the material for the study of general problems.

In view of these considerations it is somewhat surprising that more biometric work has not been done with the social insects as material. So far as the writer is aware there has as yet been but one quantitative study of variation in ants, that of Kellogg and Bell (10). With bees the case is somewhat better. Here we have, besides the earlier work of Koschewnikow (11, 12) and Bachmetjew (1, 2, 3, 4, 5 and 6) the careful quantitative studies of Casteel and Phillips (7), Kellogg and Bell (*loc. cit.*) and Kellogg (9). Miss Entemann's (8) study of variation in the coloration of *Polistes,* which was quantitative in character, was the only study of the kind on wasps before 1907.

During the last two years two papers dealing with variation in wasps have been published from Pearson's Biometric Laboratory. The first of these, by Wright, Lee and Pearson (16), deals with the results of a study of the variation exhibited by the individuals of the several castes (queens, drones and workers) taken from a single nest of *Vespa vulgaris*. From the material contained in this nest it was possible to get measurements of 129 queens, 130 drones and 129 workers. The length and greatest breadth of each wing were measured, as well as the dimensions of various "cells" marked off by the wing veins. Altogether seven absolute measurements were made and from these six indices were calculated. The first point brought out by the measurements is that the wings of queens are larger than those of drones, and the drones in turn possess larger wings than the workers. There are some differences in the proportions of the wings in the three castes, though these differences are not relatively so great as those in absolute size. There are only slight differences, either in absolute size or proportions, between the wings of the two sides of the body. All these are facts easily enough ascertainable by direct observation. The biometrical expression makes more precise and accurate what was already known. In regard to the absolute size of the wing the worker is absolutely and relatively more variable than the drone, and the drone than the queen. In regard to the proportions of the wing (as measured by the indices) this relation is nearly reversed, though the differences are much smaller; the drone is slightly less variable than the worker, and the queen is less variable than either. The degree of relative variability, as measured by the coefficient of variation, is exceedingly small for some of the dimensions of the wasp's wing. The mean coefficients for queens' wings are for absolute dimensions 1.57 (right wing) and 1.54 (left wing) and for indices 1.28 (right wing) and 1.25 (left wing). These are among the smallest variabilities yet recorded.

The highest correlations between wing dimensions were found in the workers, and (with the exception of a single pair of characters) the lowest correlations in the queens, the drones taking an intermediate position. The index correlations were found to be nearly all negligibly small. On the basis of this result the suggestion is made that these wing proportions, as given in the indices, ought to be useful taxonomic characters.

The point of greatest interest brought out by this first study of wasp variation is the relative variability exhibited in the different castes, as compared with what has been found for bees. There can be no doubt apparently that in bees the drones are *more* variable than the workers. This result was announced on rather dubious statistical grounds by Casteel and Phillips (7), criticized by Lutz (13), but abundantly confirmed by Kellogg (9) and by Pearson's (16, p. 422) reductions of the data of Casteel and Phillips. In the wasp the drones are distinctly *less* variable than the workers.

A second study of variation in wasps already referred to has appeared quite recently. The work was done by Thomson, Bell and Pearson (14) and deals with the comparative variability of queens taken from a single nest, on the one hand, and of an equally large sample of queens, presumably taken at random from the "general population" of queens, on the other hand. Such a comparison is obviously of a great deal of interest biologically. First as to the source of material for the study: The queens from a single nest were the same ones that were used in the first study discussed above. The "general population" queens were obtained in the following way:

> The queens for this second investigation were obtained in the spring of 1908 in the neighborhood of Gerard's Cross. As soon as the first queen wasp appeared, a reward of 1 *d.* was offered for each queen wasp brought, and considerably over 200 were then rapidly collected. . . . The specimens came in small numbers, sometimes one at a time, often alive, and there is no reason to doubt that they represent a genuine sample of the queen wasps of the autumn of 1907, which survived the winter and were starting in the spring of 1908 to establish their nests.

This "general population" material collected in the way described would appear to be open to serious criticism from several points of view. In the first place, as pointed out by the authors, these "general population" queens represent a different locality and season of the year from the single nest queens with which they are compared. Nothing is known about the effect of environmental and seasonal influences upon the characters studied. In the second place, it is difficult to find in the sentences quoted above, which is all the information that is offered touching the point, any real concrete evidence that these queens collected on the bounty system really were, as a matter of fact, a truly random sample of the "general population" of queen wasps. Since they all came from one restricted locality more than a suspicion is raised, considering the habits of wasps and the relative frequency and distribution of wasp nests, that they may all have emanated from a very few original nests. If they did the whole paper is vitiated. It is not of course meant to assert that they *did* come from a few nests only, but it is desired merely to point out that the authors of the paper apparently have no evidence (and made no attempt to get any) that they *did not* so originate. It might be held that the values of the biometric constants calculated for these queens constitute evidence that they are a random sample of the general population. But this is merely arguing in a circle. It is precisely equivalent to saying that two and two make four *because* four is made by two and two. The constants are, in the first instance, calculated and their values are subsequently used in the discussion on the assumption that the material is really a random sample of the general population. The discussion of the biological import of the constants has no significance if this assumption is not true. This being so, it is not feasible to turn around and say that the values of the constants prove the randomness of the material.

On the basis of this rather dubious material the discussion of a very interesting question of inheritance is undertaken. The characters dealt with are the same as those of the former paper. The first point brought out is that there is a slight but definite differentiation between the ''single nest'' and the ''general population'' queens. The authors state that they are not clear as to what is the cause of the differentiation. The main point of the paper turns on the relative variability of the two groups. Taking first the standard deviations (the coefficients of variation show the same thing), it appears that the ''single nest'' queens are roughly only just about half as variable as the ''general population'' queens. A long discussion follows regarding the question of whether the amount of this reduction in variability in the single nest is what would be expected on the basis of the law of ancestral inheritance. The general outcome is that it is not! There are, however, so many biological factors about which the authors avowedly have no data at all, concerned in the production and interpretation of the observed results, to say nothing of the general difficulty about the randomness of the ''general population'' sample, that the discussion fails to be very convincing in any direction. This particular case well illustrates a tendency which seems likely to do a good deal of harm to the biometrical cause, so far, at least, as biologists are concerned. The whole discussion of inheritance in wasps in this paper rests on a series of premises and assumptions regarding wasp *biology*, which are made without any attempt whatever first to learn by direct investigation the actual biological facts. This method of developing a long and involved theoretical argument, with very far-reaching ultimate conclusions, upon an exceedingly slender basis of facts, gives such discussions of heredity a highly academic, not to say Pickwickian, flavor. In general one can not help feeling that if one becomes seized of a desire to know how characters are inherited in wasps the direct and straightforward way to set about easing his intellectual pangs is to breed wasps under controlled experimental conditions and observe the results. The technical difficulties of dealing with this particular material in this way would doubtless be considerable, but probably not absolutely insurmountable. In any event it would seem that indirect methods of studying inheritance should be only a sort of last resort when direct methods have failed or can not be applied.

The correlations are also found to be reduced in the nest as compared with the "general" population. The amount of this reduction is shown to be that which would be expected as a statistical consequence of the observed reduction in variability of the one population compared with the other.

Warren's (15) termite paper contains a wealth of interesting biological data. It presents the constants calculated from a very extensive series of measurements of the character head breadth in the different castes of several species of South African termites. The bulk of the data are from one species, *Termes natalensis*. A typical nest of this species contains the following kinds of individuals: (1) A single king and a single queen, these being the only sexually mature forms present; (2) soldiers of two sizes, asexual; (3) workers of two sizes, asexual; (4) winged males and females, not sexually mature; (5) young or immature members of castes (2), (3) and (4). Some of the more interesting results which come out of this work are as follows:

There is considerable seasonal variation in the individuals of the same nest. The mean is smallest and the absolute variability greatest in material taken in November, and the mean is greatest and the absolute variability least in March material. Warren offers the following explanation of this result:

> This seasonal variation probably arises from two causes at least: (1) the elimination of the physically unfit, (2) post- "adult" growth. With reference to the first cause it may be noticed that it is very probable that more individuals arrive at maturity from August to November, that is during the first rains, than at other seasons, and therefore the stunted adults will be more abundant during this period, with the result that the mean would be lowered and the standard deviation would be raised. By the time that March arrives the small and weakly individuals of the nest are likely to have died, and consequently the mean will be raised and the standard deviation will be diminished. The second, and perhaps more potent influence, is that the so-called "adults" appear to grow to a certain extent even after their exoskeleton has become hard and yellow.

The workers of *T. natalensis* are on the average less variable than the soldiers. The ratio of worker variability to soldier variability is about 0.8. The sexual castes are less variable than the asexual, both in *T. natalensis* and as an average of the study of other species of termites. The variability of a "general population" of *T. natalensis* obtained by adding together random samples of 100 individuals each (the small soldiers being the caste chosen) from 30 different nests. The coefficient of variability obtained from this population was 7.02 as compared with 3.02 as the average coefficient for single families (*i. e.*, nests). There is thus a reduction here, as in the wasps, of about 50 per cent. in variability in passing from "general population" to single nest. The "inter-nest" correlation of the means between any two castes is about 0.9. The author points out that:

> It is curious that the correlation between similar castes (large and small soldiers) does not appear to be greater than that between dissimilar castes (small soldiers and large workers).

From a study of the correlation between the coefficients of variation it appears that:

> In any given nest when one caste happens, say, to be particularly variable, it does not follow that every other caste is correspondingly variable. From *a priori* reasons one would have expected that the variability of the different castes in a nest would have been closely related, if the variability is to be regarded as an inherited character. If, on the other hand, the variability is to be mainly referred to nurture or to the general environmental conditions, the above results are intelligible.

Bachmetjew (5, 6) has developed an intricate and highly organized theory regarding the existence and origin of polymorphism in the normal bee colony. This theory is supposed by its author to rest upon a solid "statistisch-analytische" foundation. In reality this statistical "foundation" is of such character as to make one wonder at times whether the author (by training a physicist and presumably familiar through that discipline with the elementary principles at least of the mathematical theory of probability) is really serious, or whether he is not perpetrating a great biometric practical joke. The character with which Bachmetjew has dealt in bees is the number of hooks on the anterior margin of the posterior wings. His central thesis, which he at once proves (?) and then forthwith applies to aid in still greater biologico-metrical onslaughts, is to the effect that if a group of individuals (size of group not specified and apparently not regarded as in any way important) shows *two* observed maxima of frequency, with respect to a character expressed in integral or discrete units (*e. g.*, hook number), then the eggs (or seeds) from which the individuals of the group originated were fertilized. If, on the other hand, but *one* maximum of frequency is to be observed, then the individuals developed parthenogenetically. This neat, though somewhat far-reaching, generalization, rests solely and simply on the location by *inspection* alone of modes or maxima of frequency in samples of from about 50 to 150 individuals! Nowhere in Bachmetjew's papers is there any indication of such a concept as that the observed frequencies might have a probable error ever having disturbed the placid progress of the reasoning.

To give these comments point some of Bachmetjew's frequency distributions may be examined. Here are some distributions *supposed* (with a mathematical naïveté probably nowhere to be paralleled in scientific literature) to show two maxima of frequency at the points indicated by the bold faced type (Bachmetjew (5)).

A. (p. 6)	B. (p. 7)	C. (p. 7)	D. (p. 9)
1	1	1	2
2	1	9	5
9	7	11	13
11	**28**	**27**	**19**
21	**31**	**27**	15
21	18	22	**15**
21	9	9	11
16	2	2	80
5	2	2	
2	99	110	
1			
110			

It certainly demands the most consummate scientific insight to discern why the two modes in A and C, for example, should be located as they are. And again the unenlightened statistician wonders what it is about the second 15 in D which makes it a mode rather than the first 15. Is it possessed of a different essence or *aura*, say a sort of transcendental "fifteenness"?

Or again, to take but one more example, who would have supposed that distribution E had two modes while F had but one? (Bachmetjew (5)).

E. (p. 8)	F. (p. 19)
2	1
5	1
10	1
22	4
24	8
17	14

12	15
8	18
100	20
	10
	4
	4
	100

This is indeed esoteric biometry! So much so that it seems hardly advisable to review the theoretical considerations which are made to flow from the sort of statistics presented.

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EXPERIMENTAL ZOOLOGY

The Effects of Extirpation and of Transplantation of the Reproductive Organs in Insects.—Meisenheimer[1] has carried on extensive experiments with moths for the purpose of determining whether the differentiation of the accessory genital organs and of secondary sexual characters is dependent on the ovary and testis or whether their development is independent of the sex glands. The material used was chiefly the moth *Lymantria* (*Oeneria*) *dispar* L., which has a marked sexual dimorphism and recovers well from the effects of operation. The caterpillar passes through five moults before pupation, the first moult taking place about five days after hatching, and each later one in from eight to twelve days, according to temperature; pupation takes place in about six days after the last moult and lasts for three or four weeks. The operations consisted of removal of sex glands, removal of anlage of accessory genital apparatus, transplantation of sex gland of the opposite sex, and removal of wing anlage. The operations were done on all six caterpillar stages, the extirpation of sex glands being done by means of an electric needle in the first two stages, and by a knife in later stages. The mortality was very great, only 51 caterpillars surviving the electrical operation out of 1,250, and 176 out of 537 surviving when the organ was cut out.

In moths from caterpillars whose testes had been removed, the vasa deferentia ended blindly; otherwise the accessory sexual apparatus was perfectly normal. In one case, the vasa deferentia had fused at their free ends, owing to their proximity at the time of healing. The secondary sexual characters, such as the size, coloring and markings of the wings, were of the normal male type. When, in addition to castration, the anlage of the accessory sexual organs, including the vesiculæ seminales, ductus ejaculatorius, penis and most of the vasa deferentia, was removed,

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[1] Experimentelle Studien zur Soma- und Geschlechts-Differenzierung.'' Erster Beitrag. Von Prof. Johannes Meisenheimer. Jena, Gustav Fischer, 1909.